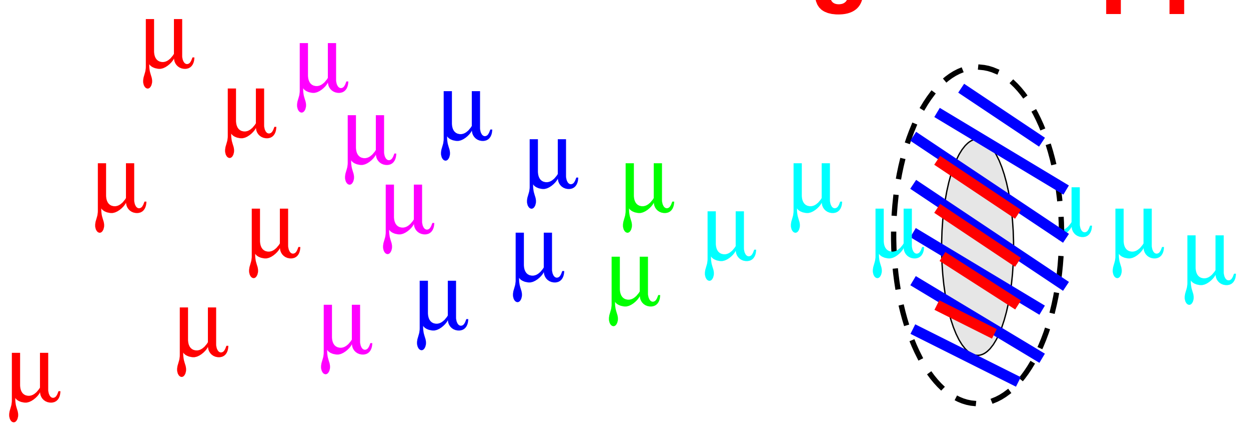
University of Chicago

Beam Profiling:
making it happen



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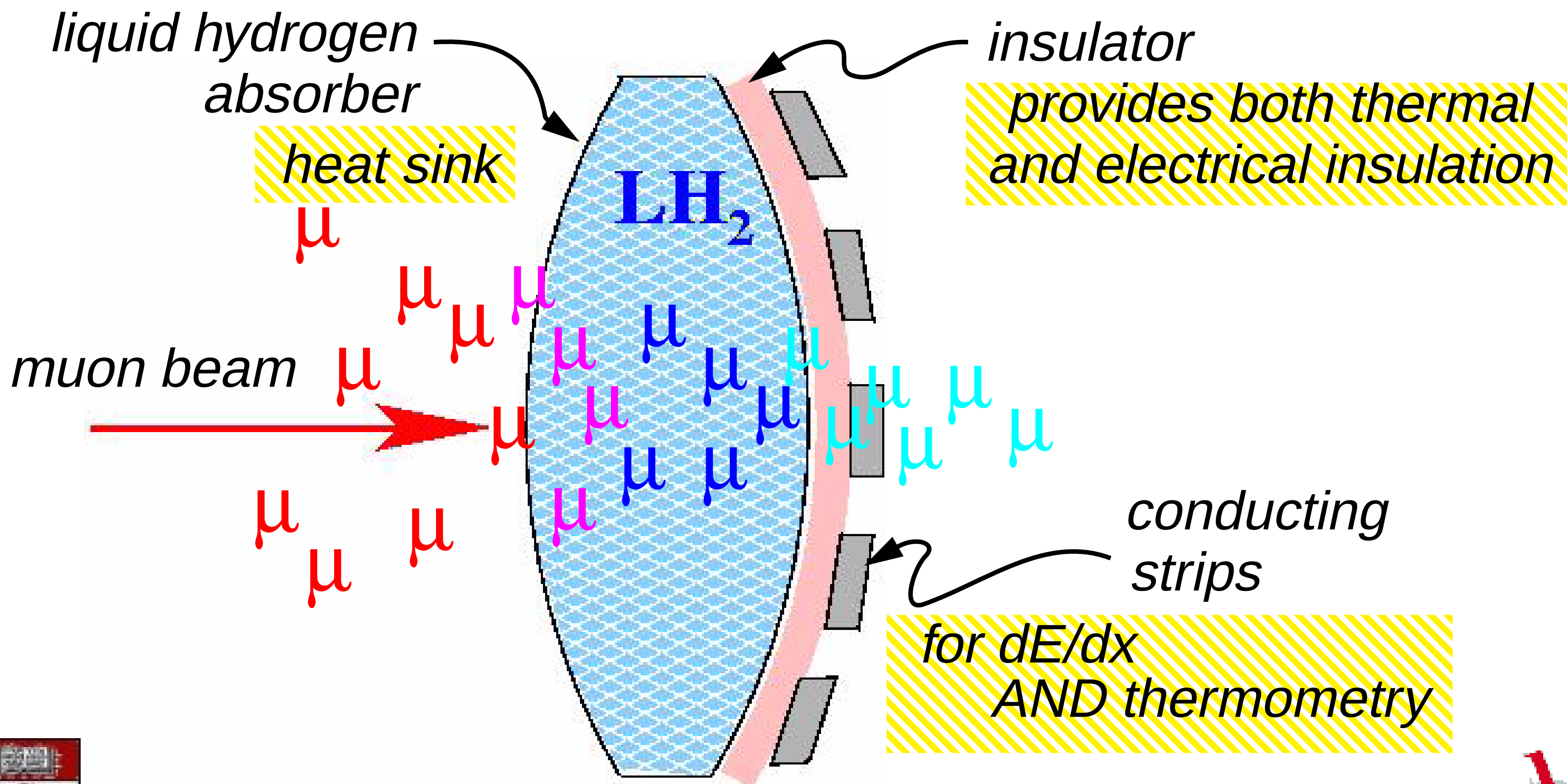
Technical support: Elizabeth Pod (mechanical)
Harold Sanders (electronics)
John Greene (Argonne)

BOLOMETRY

1) muons traverse bolometric strips, depositing energy
2) deposited dE/dx heats the strip
3) muon is detected through change in voltage on strip because resistance of strip is temperature sensitive
4) hydrogen absorber serves as heat sink to cool strip



AN ELEGANT SOLUTION

...for detection and profiling of the muon beam

advantages

Minimal amount of material in the path of the beam.

Existing liquid hydrogen used for cooling doubles as an absorber.

Sensitive only to high energy particles, not noise from low enrgy background.

challenges

Finding the optimal media for bolometry and insulation.

Fabrication.

Designing electronics with high gain, high bandwidth, and very low noise.

SIMULATIONS

System has been modelled assuming:

Beam

-groups of 2 x10^{12} of 100 ns duration

-gaussian beam with sigma=5cm

Apparatus

-300 micron thick Al window

-bolometer with 1000nm of MgF2 used as insulator and 100 nm Ni bolometeric strips

Results:

thermal time constants ~ 5-50 microseconds

Energy deposited per bunch: 0.166 J

>15 K average temperature increase!!

BOLOMETERS

Will be fabricated directly on absorber window using evaporation, sputtering, dipping, spraying...whatever.

John Greene, a nuclear target specialist at Argonne, is performing evaporations. He has tried several insulating materials including MgF_2, and several conducting materials, including Nickel.

Several iterations on materials, and thickness may be required to find the optimal solution, and John is very busy!

We now have the capability to perform thin film evaporations in-house at the University of Chicago.

MATERIALS PART I: INSULATORS

- must provide electrical isolation of the strips
- must be thermally insulating
- must withstand high radiation environment

Iteration 1: Evaporated layers of salts:
magnesium flouride, aluminum oxide, sodium chloride

electrical insulation achieved(?) but not mechanically/chemically robust

Iteration 2: (in progress) Depositing layers of dielectric material (i.e. silicon dioxide, silicon nitride, polyimide) via spraying or dipping and baking.

BOLOMETRIC MATERIAL

Requirements

-must be high Z

muon must deposit measurable dE/dx

-must have a large TCR curve near liquid hydrogen temperatures

must be sensitive to small changes in T

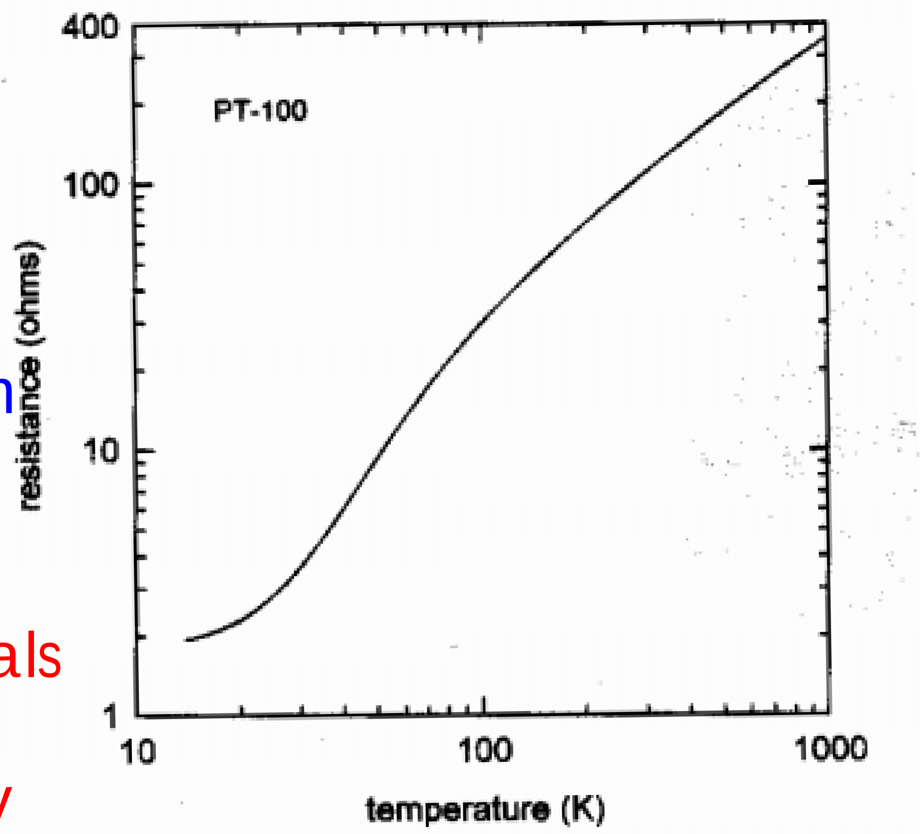
-must be radiation hard

Platinum

often used in thermometry

rad-hard

may be e-beam evaporated or sputtered



other pure metals dominated by electron-impuity scattering at low T

Other candidates:

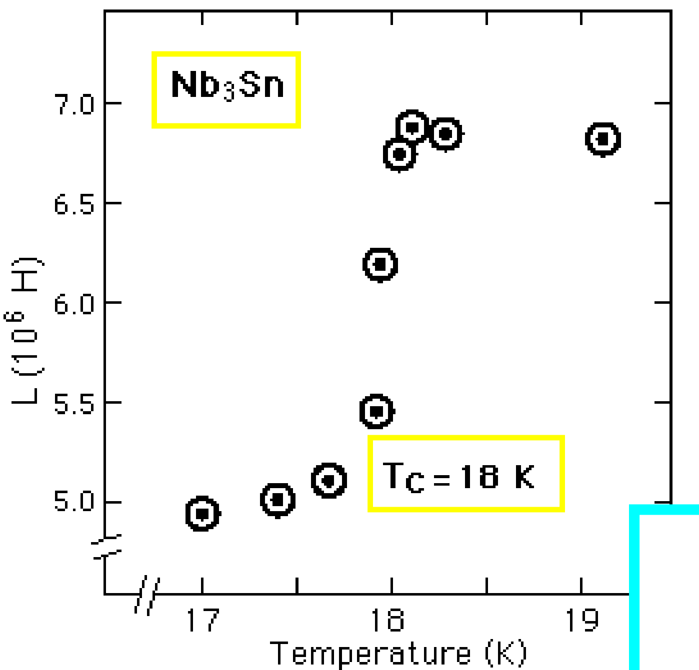
- semiconductors (doped Ge)
- alloys
- disordered materials

SUPERCONDUCTORS?

Type II Superconductors:

-will superconduct in magnetic fields

-some have Tc near LH2 temperatures



Niobium Tin

Tc=18K

TCR slope may be tuned by adding impurities

(evaporable) easy fabrication?

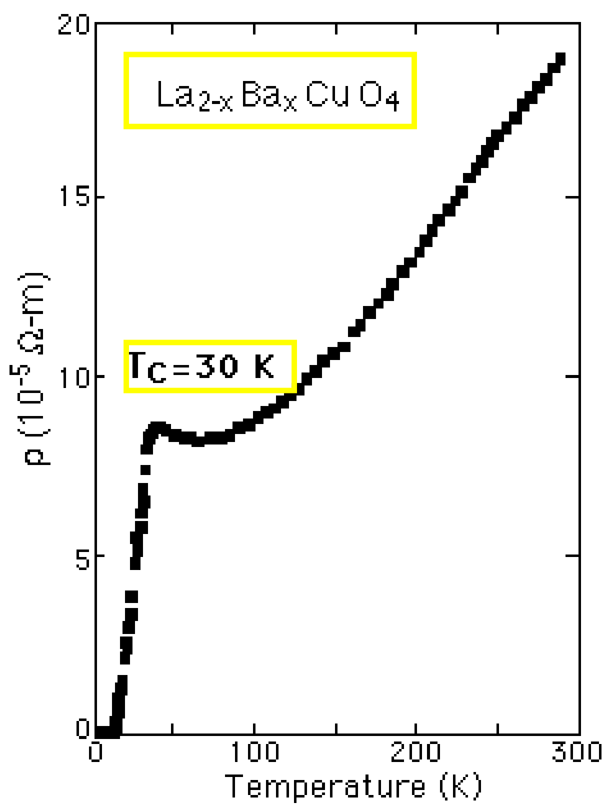
La-Ba-Cu-O

Tc=30K

ceramic

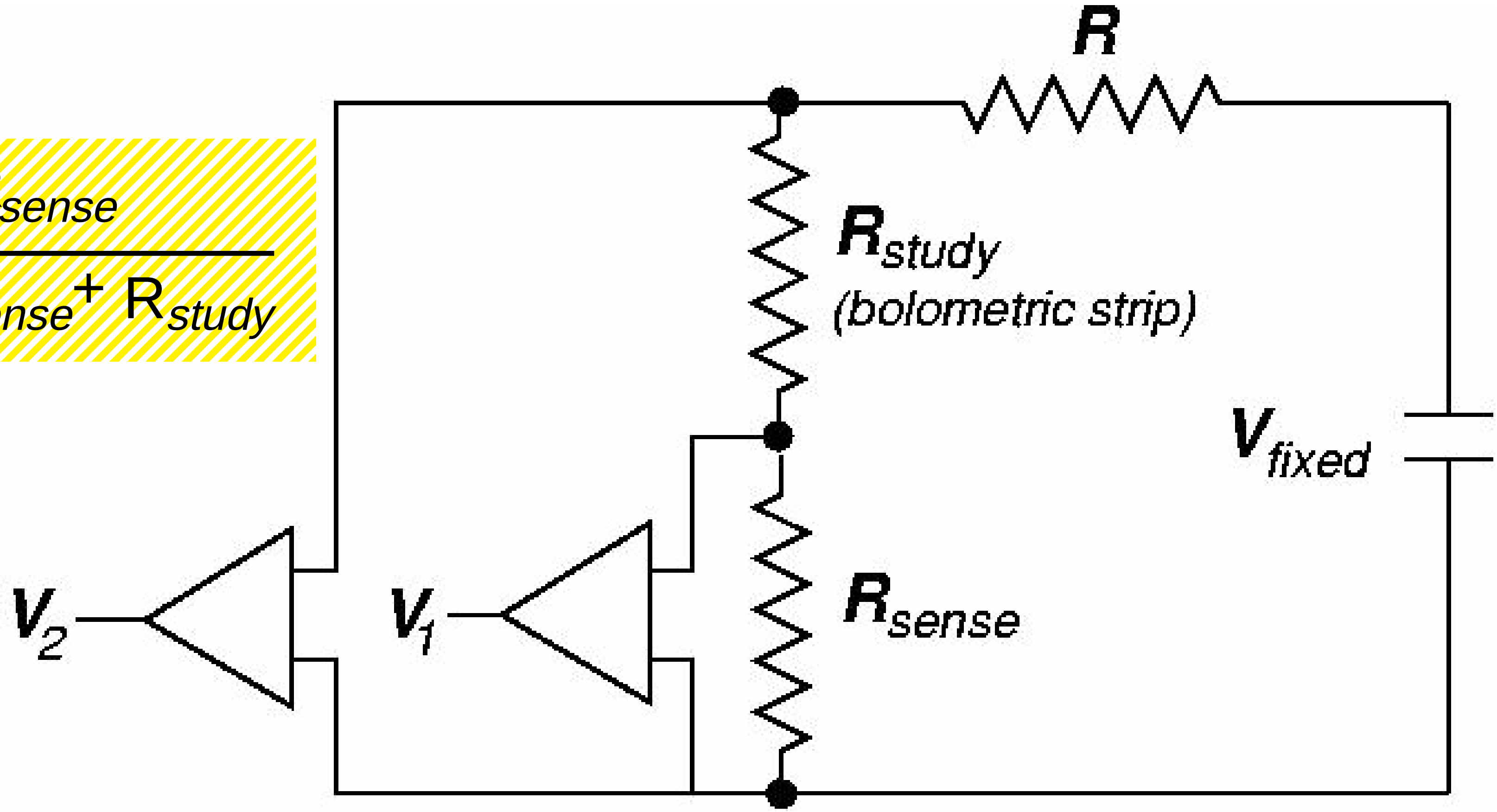
(may not be adequately rad-hard!)

may have to outsource fabrication



ELECTRONICS

$$\frac{V_1}{V_2} = \frac{R_{sense}}{R_{sense} + R_{study}}$$



- Must have very low current (so electric power dissipation does not heat strips, obscuring measurement)

-Rsense must be <<Rstudy

-very low noise

ELECTRONICS

We are studying commercially available instrumentation amplifiers

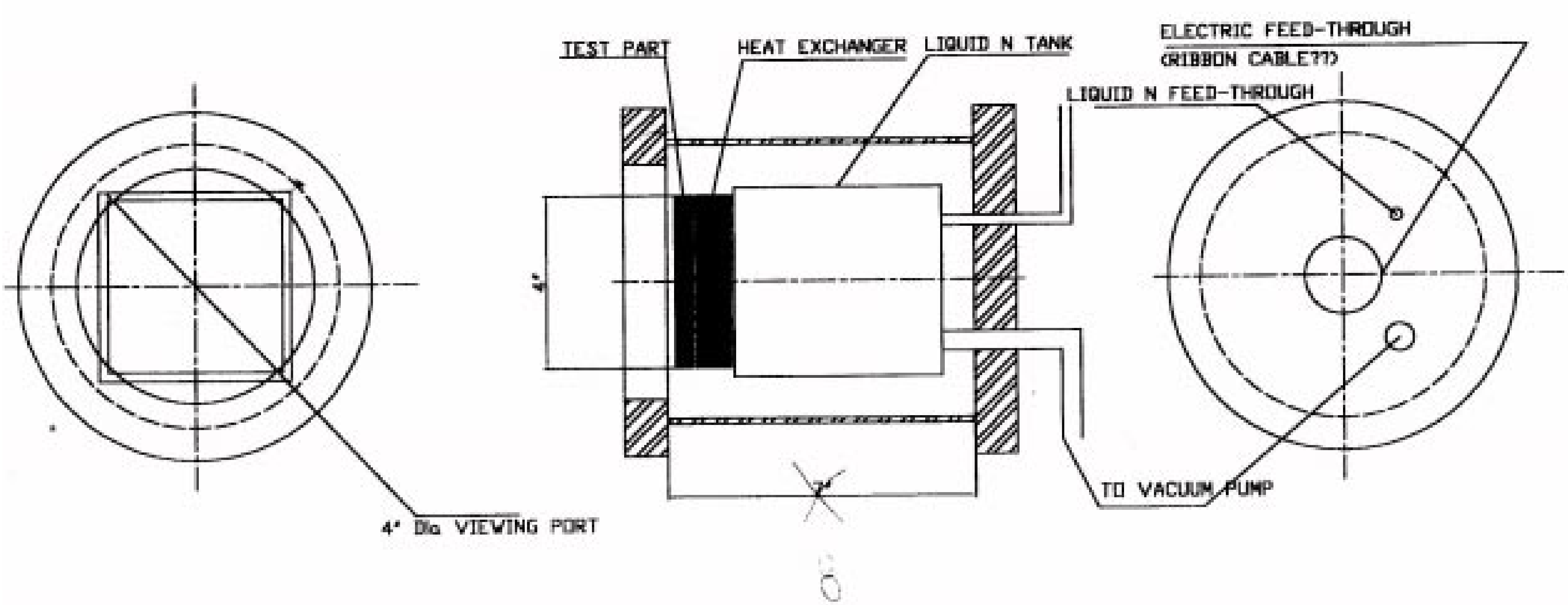
- must have large gain (~1000)
- must have a large bandwidth
- must have very low noise

PROOF OF PRINCIPLE TEST

A test “window” has been constructed at U of C to demonstrate that bolometry works.

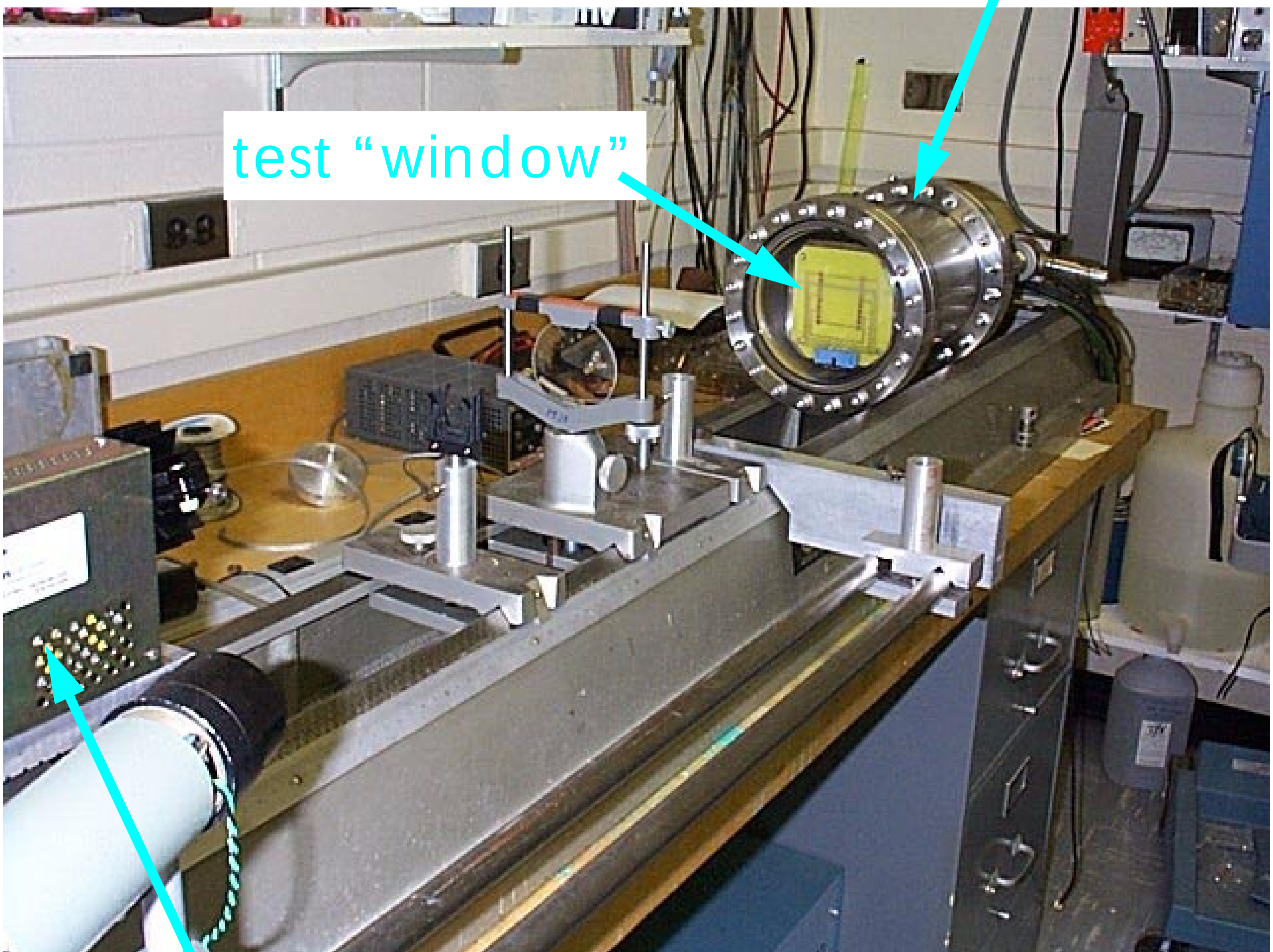
It is cooled with liquid nitrogen.

Beam pulses simulated with a xenon flashlamp.



TEST SETUP

vacuum enclosure



xenon flashlamp

Needed to complete proof of principle test:

- amplifier
- a bolometer!

Test Bolometer

Need bolometric material with large TCR curve near liquid Nitrogen temperatures.

We have succeeded in evaporating Nickel.

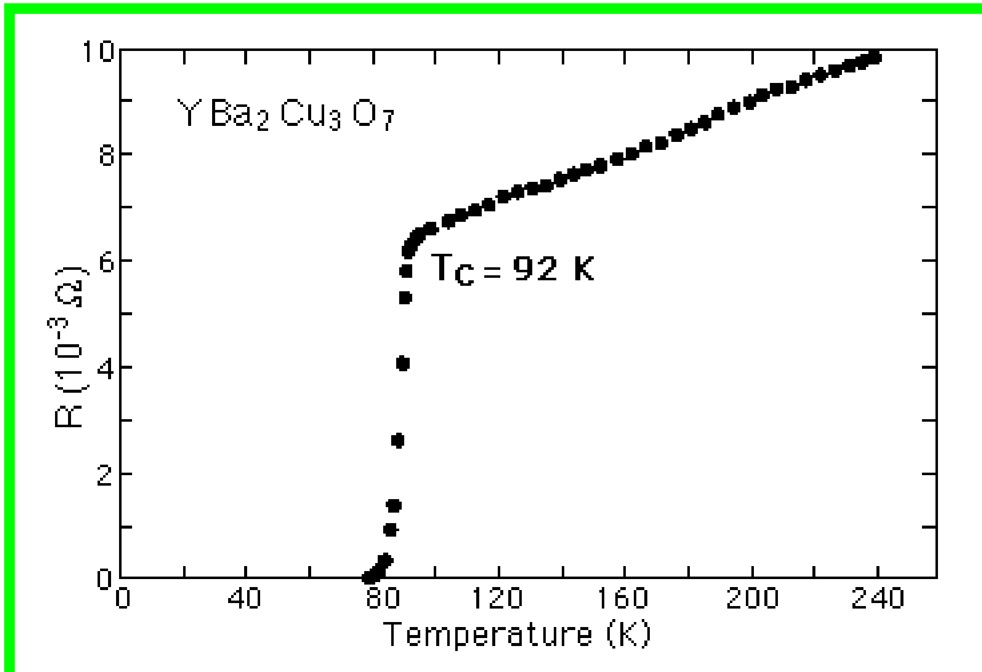
Ideal high temperature superconductors exist with Tc near liquid nitrogen temperatures.

Y-Ba-Cu-O

Cheap and readily available.

Tc near LN (77K).

Can be formed into a thin film (although it may require commercial help!)



STRAIN GAUGES

Strain gauges operate on a similar principle to bolometers...

-bolometers change resistivity in response to changes in temperature.

-strain gauges change resistivity in response to deformation

It might be desirable to build a strain gauge into the cooling channel as a failsafe against window rupture.

Idea: evaporate "strain gauge strips" on insulating layer of bolometer.

NASA has evaporated strain gauges on the surface of space vehicles.

optimized for high temperature operation (atmospheric re-entry)

Could we use the same technology for low-temperature applications???

EVAPORATED STRAIN GAUGES:

ADVANTAGES:

-nothing to glue

-no additional sets of wires

-less material in the beam path

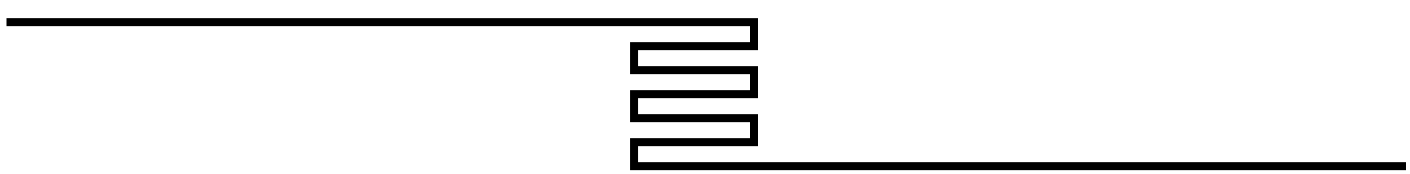
CHALLENGES:

-finding an appropriate material (Constantan?)

must respond differently to changes in temperature versus changes in strain

must be easily evaporated

-finding a geometry which can be read out from the ends but sensitive to strain in the thinnest center area



NEAR FUTURE

THINGS ARE MOVING QUICKLY!

Hope to demonstrate proof of principle by the end of May.

We now have the capability of performing thin film evaporations at U of C.

Actively researching strain gauge technology and strain sensitive materials to determine whether an evaporated strain gauge is feasible for our application (with some help here from Christine Darve).